

Note on spin carried by quarks

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Abstract

We note that recent results on the role of final state interactions in deep inelastic scattering make more complicated an extraction of a nucleon spin fraction carried by quarks from the experimental data obtained in deep inelastic scattering.

Crucial results on the essential role of final state interactions in the interpretation of structure functions $F_i(x, Q^2)$ in deep inelastic scattering have been obtained recently [1]. It appeared that final state interactions of the struck quark with proton remnants cannot be eliminated and this fact invalidates interpretation of the structure functions as parton probability densities. These results lead to the important phenomenological implications, in particular, they provide significant single spin asymmetries in SIDIS [2, 3] and Drell–Yan processes [4].

It is evident that arguments of [1] can be applied to the polarized structure functions $G_i(x, Q^2)$ as well. Experimentally measured quark spin distributions $\widetilde{\Delta}q(x, Q^2)$ will include then rescattering effects related to the presence of the path ordered exponent in their definitions as Fourier transform of the matrix elements of the axial vector current operator similar to the case of unpolarized quark distributions [1, 4]. By definition¹ quark spin densities $q_\uparrow(x, Q^2)$ and $q_\downarrow(x, Q^2)$ are the probability densities to find a quark of flavor q with a given helicity value and momentum fraction in the hadron wavefunction resolved in the transverse plane with the resolution scale determined by Q^2 . This allow us to interpret the first moment of the function

$$\Delta q(x, Q^2) = q_\uparrow(x, Q^2) - q_\downarrow(x, Q^2) + \bar{q}_\uparrow(x, Q^2) - \bar{q}_\downarrow(x, Q^2)$$

as the net fractions of the nucleon spin carried by quarks of particular flavor, and total fraction of hadron spin carried by quarks Σ is a sum of the first moments over all flavors. Thus, we immediately arrive to conclusion that it is more difficult to extract in a usual way quark the spin densities $\Delta q(x, Q^2)$ from the experimentally measured polarized structure functions $g_{1,2}(x, Q^2)$. Indeed, rescattering affects most strongly the region of small x and we can then expect here a maximal deviation of the functions $\widetilde{\Delta}q(x, Q^2)$ from the usual quark spin densities $\Delta q(x, Q^2)$. At the same time the region of small x is most important for the calculation of the net spin carried by quarks and antiquarks. Since, the structure functions are experimentally measured in the limited region of x the cancellation of the rescattering effects, which is valid for $\int_0^1 \Delta q(x, Q^2)$, may not take place for the limited integration region.

It is well known now that the functions $\widetilde{\Delta}q(x, Q^2)$ and $\Delta q(x, Q^2)$ can be different due to perturbative contribution of an axial vector anomaly and this way to treat “spin crisis” was proposed at its early stage [6, 7]. Rescattering effects adherent to both polarized and unpolarized structure functions have a different origin.

¹We apply definition of quark densities, which allow straightforward interpretations of the experimental results; thorough discussion of definitions of parton densities has been given recently in [5].

To this end, the conclusion on the increasing difficulty of the extraction of fraction of spin carried by quarks from the experimental data in deep inelastic scattering due to rescattering effects seems inevitable and the fundamental reason for this conclusion is that we have to deal with not free but interacting fields. This interaction leads to strong coherence effects in the interaction of virtual photon with hadron. Account for such effects can be done in the model way. For example, modelling of these effects in the nonperturbative approach based on unitarity has been performed in [8].

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